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Composite bulk Heat Insulation Made of loose Mineral and Organic Aggregate

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Abstract **–The task of building energy-efficiency is getting more important. Every house owner wishes to save up exploitation costs of heating, cooling, hot water production, ventilation, etc. and find cost-effective investments. One of the ways to reduce greenhouse gas emissions (GHGE) is to minimize the heat transfer through the building by insulating it. Loose heat insulation is a good alternative to traditional board insulation, it is simple in use and cost-effective. Main drawback of this insulation is tendency to compact during exploitation. In the frame of this research composite loose heat insulation is elaborated, consisting on porous mineral foamed glass aggregate and local organic fiber materials (hemp and flaxen shives). Composite bulk insulation is an alternative solution which combines heat insulating properties and mechanical stability.**

Keywords – **Composite insulation, foamed glass, heat conductivity, shives.**

I. Introduction

Creation of "green" building, using local resources and saving of energy are the most important tasks in modern construction sector, where the energy-efficient exploitation of the building is getting more important [1]–[4]. At present in the Baltic states required value for wall thermal transmittance coefficient *U* should not be more than 0.18k W/mK, where k is factor of temperature [5]. It depends on climatic conditions of the location, indoor design temperature according to use of building and the average outdoor air temperature during the heating season.

To achieve this destination, the production of effective and inexpensive heat insulation materials is necessary. Loose heat insulation is a good alternative instead of traditional board insulation. Porous aggregates (made of recycled materials, for example foamed glass) and organic aggregates of local raw materials (waste of processing agriculture products, for example hemp and flaxen shives, peels of wheat) could be as appropriate materials in modern low-cost frame building systems. These mentioned aggregates and their mixtures are mostly local materials and in the future will promote the development of construction sector in Latvia. There are a lot of advantages using these aggregates, for example, inexpensive local materials (shives and peels), possibilities for use recycled materials, complicated space filling without gaps and improved sound insulation properties. The main disadvantage of loose heat insulation is self-compaction effect during the exploitation [6]. Depending on the structure of natural fiber materials, they have higher moisture sensitivity comparing to mineral materials [7]. There is also necessary to provide fire resistance and biological persistence, especially materials, which are made of cellulosic fibres [8].

According to [9], GHGE needs to be reduced by 20 %. All buildings are being renovated by approaching lower energy consumption and lower values of heat conductivity *U* [3], [10]. Modern direction of thermal protection of buildings is developing upon ecological building materials. That is why loose insulation (consisted of locally available, cost-effective raw components, lower thermal conductivity and with minimum energy input) is proposed and researched [5], [11]–[12].

During the programme of Baltic Sea Region in the project "Alternative of energy – sustainable energy strategies as an opportunity for regional development" Latvia was created new heat insulation material "Kanaizols" which consists of 75–80 % hemp shives and 20–25 % fibres of cellulose. Heat transmission coefficient λ of "Kanaizols" is 0.061 W/mK [13]–[14]. In comparison to one of the most commercially popular in Latvia loose heat insulation material „Ekowool" ($\lambda = 0.039$ W/mK, which is one of the lowest from the traditional loose materials), which consists of 81 % wasted paper supplemented with seven percentage sodium tetra borate and twelve percentage boric acid [*www.latvijas-ekovate.lv*], "Kanaizols" heat transmission coefficient is still not the best result. "Ekowool" is ecological and fireproof loose heat insulation material produced from recycled fibres of cellulose. It's loose density and transmission coefficient λ are one of the best index, that's why authors uses "Ekowool" as a reference material to compare experimental data. There is no necessary to compare experimental data to bulk mineral wool (for example, PAROC BLT9), because it's loose density and transmission coefficient λ are very similar to "Ekowool".

Summarising basic properties of mineral and organic wool loose insulation, it may be claimed that organic wool insulation has less good thermal insulation [7], but it is combustible and dimensionally non-stable. At the same time, mineral loose insulation, such as granulated foamed glass, is non-combustible, dimensionally stable, but it is characterised by increased value of heat conductivity. The task of this study is obtaining of composite loose insulation which combines positive properties of mineral and organic component.

II. Materials

In the research two types of loose components were used: mineral and organic. Raw materials and their mixtures were selected for determination and comparison of thermal insulating and physical-mechanical properties.

A. Mineral Components

As a mineral component there was used granulated foamed glass, (see Fig. 1) which is produced from recycled material and notable with high porosity, fire resistance and mechanical stability. Heat transmission coefficient λ of this material is ranged from 0.059 to 0.080 W/mK (according to Stikloporas JSC, Lithuania). In this research two foamed glass granule fractions were used: 1 to 4 mm and 4 to 8 mm.

Fig. 1. Foamed glass, fraction 4 to 8 mm (ruler units in cm).

B. Organic Components

Hemp shives, flaxen shives (see Fig. 2 and Fig. 3) and peels of wheat, were used as natural organic components. Mentioned materials are by-products agricultural industry and are more lightweight than mineral components.

In the Fig. 2 it can be seen that flaxen shives are quite small, only 13 mm to 14 mm in length and 1 mm to 1.5 mm in width, but hemp shives are more coarse comparing to flaxen shives – 2 mm to 3 mm in width.

Fig. 2. Flaxen shives (ruler units in cm).

C. Composite Mixtures of Organic and Mineral Components

This study based on creating composite loose insulation consisting of mineral granulated foamed glass and organic hemp and flaxen shives components. Physical, mechanical and thermal properties of created composite loose insulation are determined compared with properties of traditional loose heat insulation materials.

Fig. 3. Hemp shives (ruler units in cm).

Basic properties of raw materials used in this study, such as loose density, the coefficient of heat transmission, reaction to fire etc., are summarised in the Table I.

TABLE I

BASIC PROPERTIES OF LOOSE INSULATION

Property	**Component 1: Foamed glass gravel**	**Component 2: Shives (hemp and flaxen)**	**"Ekowool" (for comparing)**
Origination	Mineral	Organic	Organic
Loose Density, kg/m^3	290–300 (fraction 1–4 mm); 170–190 (fraction 4–8 mm)	70–80	30–50
Self compaction	No	Yes	Yes
Fire resistance	incombustible	combustible	semi-combustible (with special admixtures)
Sound insulation	Insufficient	Good	Good
Attractively to rodents	–	+/–	+/–
Effect of humidity	Non-hygroscopic	Hygroscopic	Semi-hyhroscopic

Data of Table I demonstrates different properties of used components. Organic wool materials are more lightweight than mineral, they show good heat transmission coefficient. Organic wool components provide good sound insulation that is mainly due to high sound absorption.

The advantages of mineral components are non-combustibility, biological persistence and material ability to maintain heat insulating properties in moist environment. But the main disadvantage is increased heat transmission coefficient.

The main idea of new composition is combination of positive properties of mineral components (fire resistance, mechanical stability) and organic components (good sound insulation), and achieving compromise solution characterizing with minimal self-compacting effect and economically effective solutions of loose heat insulation.

III. Research Methods

A. Proportions of Mixtures

The test specimens were composed and mixed up of proportions by mass (see Table II. Following raw components are used: hemp shives, flaxen shives, peels and granulated foamed glass.

TABLE II

MIX COMPOSITIONS

Designation	F	H	P	G2	G1
F + P	0.33	--	0.67	--	--
G2 + F	0.28	--	--	0.72	--
G2 + P	--	--	0.45	0.55	--
H + F	0.49	0.51	--	--	--
H + P	--	0.35	0.65	--	--
G1 + G2	--	--	--	0.38	0.62

F – flaxen shives, H – hemp shives, P – peels of wheat, G1 – foamed glass fr.1–4 mm, G2 – foamed glass fr.4–8 mm.

B. Physical Properties

Bulk densities of pure components and composite loose materials were measured. Materials were filled in measuring cylinders and smoothed down. Then loose density was defined using special steel cylinder with the diameter 100 mm and volume one litre, which has been weighed before and after filling the material.

Geometrical dimensions of material particles were measured using sliding calliper.

C. Thermal Properties

The main property of heat insulation material is reduced heat transmission coefficient λ [W/mK]. Heat resistivity R_T [m^{2}K/W] is parameter which is characterised wall construction, it depends on thickness d_i and thermal conductivity λ_i (see Eq. 1) [16]. Heat conductivity U_T [W/m^{2}K] is reversed value of heat resistivity R_T (see Eq. 2).

$$R_T = R_I + \sum_{n=1}^{n=i} \frac{d_i}{\lambda_i} + R_E \left(\frac{\mathrm{m^2 \cdot K}}{\mathrm{W}}\right) \quad (1)$$

where

R_I – defined indoor heat transmission coefficient;

R_E – defined outdoor heat transmission coefficient;

d_i – thickness of heat insulation material;

λ_I – thermal conductivity.

$$U_T = \frac{1}{R_T} \left(\frac{\mathrm{W}}{\mathrm{m^2 \cdot K}}\right) \quad (2)$$

Heat transmission coefficients λ of loose insulation materials experimentally are determined using polystyrene's box with dimensions 600 mm x 600 mm x 50 mm. The hole with dimensions 350 mm x 350 mm x 350 mm was cut out. The bottom of the box was covered with the paper and fixed with the tape (see Fig. 4). Prepared samples of loose materials were filled in the box and smoothed down.

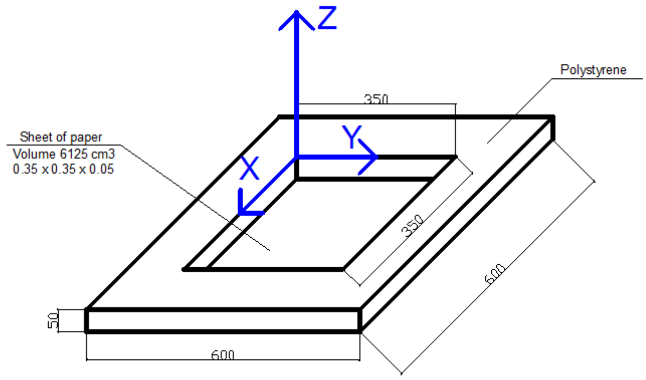

Fig. 4. Box for samples.

Then thermal conductivity of the construction materials was determined by using heat flow meter Laser Comp's FOX600 (see Fig. 5), which determines heat flux density between two stationary horizontal plates (see Eq. 3). Lower plate is warm (+20 °C), but upper plate is cooled (0 °C), the mean temperature is +20 °C and the temperature gradient is 20K.

$$q = -\lambda \frac{\Delta T}{\Delta x}, \quad (3)$$

where

q – heat flux density (W/m^2);

λ – thermal conductivity (W/mK);

$\Delta T/\Delta x$ – temperature gradient on isothermal flat surface (K/m).

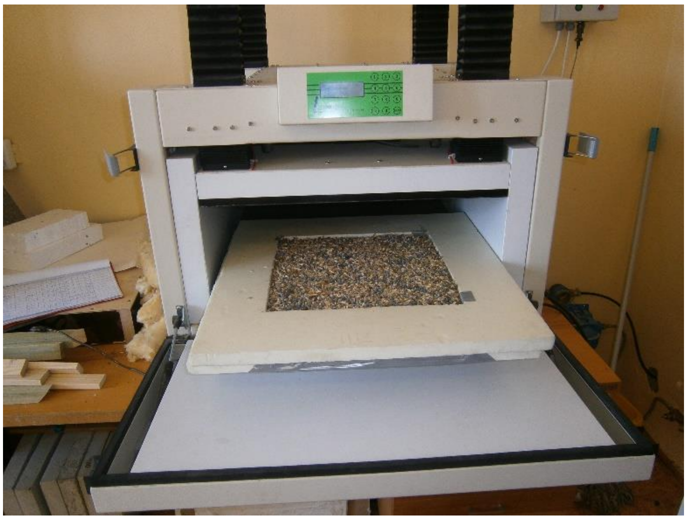

Fig. 5. Composite insulation sample prepared for conductivity test in heat flow meter.

D. Test of Deformation

In the research mechanical stability of composite mixtures of loose insulation was evaluated by compressing material in special steel cylinder (diameter 100 mm and volume 1 dm^3). Electromechanical universal testing machine Zwick Z100 was used (see Fig. 6), rate of loading 25 mm/min was applied during the test and load-deformation diagrams were obtained.

Fig. 6. The test of mechanical stability of composite insulation in Zwick Z100.

Compression – deformation curves were recorded automatically. The test duration was up to two deformation limitations – 10 % and 30 %.

IV. Results and Discussions

A. Physical Properties

Physical properties of used loose materials and their geometrical characteristics are summarized in Table III.

TABLE III
Physical Properties of Loose Materials

Property	F	H	P	G1	G2	E
Length, mm	13.63 ± 0.71	13.55 ± 0.91	10.85 ± 0.40	--	--	--
Width, mm	1.27 ± 0.07	2.56 ± 0.16	3.48 ± 0.19	--	--	--
Bulk density, kg/m^3	73.5 ± 6.6	77.7 ± 6.6	144.0 ± 6.6	297.5 ± 6.6	184.8 ± 6.6	35.0
Heat transmission coefficient, W/mK	0.049 ± 0.001	0.048 ± 0.001	0.048 ± 0.001	0.076 ± 0.001	0.064 ± 0.001	0.039

F – flaxen shives, H – hemp shives, P – peels of wheat, G1 – foamed glass fr.1–4 mm, G2 – foamed glass fr.4–8 mm, E – "Ekowool"

Analysing geometrical dimensions of used natural wool materials, it must be noted, that flaxen particles are thinner, but hemp and flaxen particles have the same length and bulk density. All used natural organic materials have the same heat transmission coefficient. At the same time, commercially available loose wool insulation "Ekowool" is characterized by lowest heat transmission coefficient (0.039 W/mK). It may be explained by small dimensions of particles, high dispersity and high porosity.

Comparing of bulk densities of different composite loose materials are summarized in the diagram (see Fig. 7).

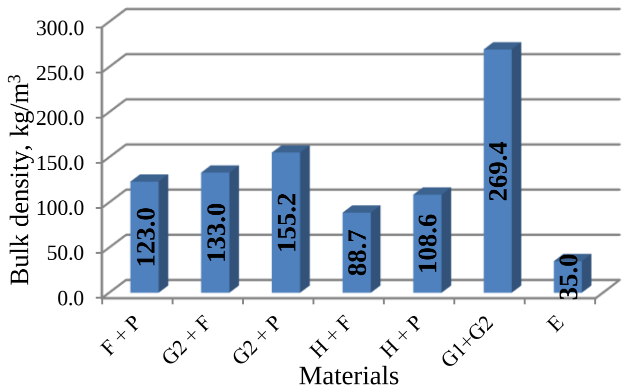

Fig. 7. Results of mixture's loose density, kg/m^3, *F – flaxen shives, H – hemp shives, P – peels of wheat, G1 – foamed glass fr.1–4 mm, G2 – foamed glass fr.4–8 mm, E – "Ekowool"*

Bulk density values of test specimens are ranged from 88.7 to 269.4 kg/m^3. Organic raw materials (shives and peels of wheat) are more lightweight than mineral components (foamed glass). Commercial wool insulation "Ekowool" has the lowest bulk density (35 kg/m^3). It could be explained by high dispersity and small dimensions of wool particles and correspondingly high value of porosity (more than 90 %). The lowest bulk density from agrucultural by-products was provided by flaxen shives 73.5 ± 6.6 kg/m^3.

The minimum bulk density of composite mineral and organic components was showed by mixture of flaxen shives and foamed glass (fr. 4–8 mm) by value of 133.0 ± 6.6 kg/m^3.

Low density also is achieved in the case of mixture of two organic components – hemp and flaxen shives (88.7 kg/m^3).

B. Heat Transmission Coefficient

Heat transmission coefficients of mixtures are shown in Fig. 8.

Heat transmission coefficient values of test specimens are within the range of 0.048–0.076 W/mK.

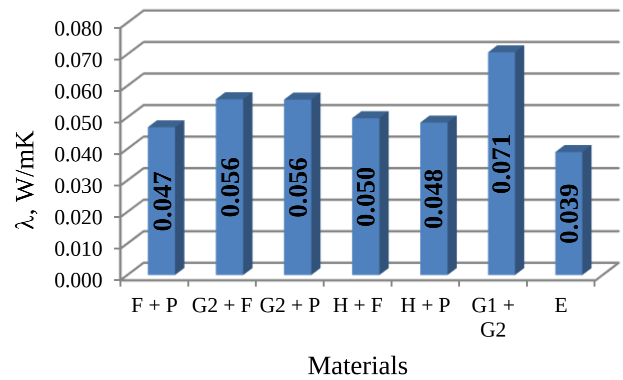

Fig. 8. Results of mixture's heat transmission coefficient, W/mK, *F – flaxen shives, H – hemp shives, P – peels of wheat, G1 – foamed glass fr.1–4 mm, G2 – foamed glass fr.4–8 mm, E – "Ekowool"*

The minimum heat transmission coefficient λ is achieved in the case of composition of flaxen shives and peels of wheat

(0.047±0.001 W/mK). It could be explained by particles packing providing more air gaps.

Equivalent values were showed other mixtures of two organic components, values varied in the range of 0.048–0.050 W/mK which is approximately 20 % more than “Ekowool”.

Experimental results shows, that adding mineral components increases heat transmission coefficient up to 15–20 % (Fig. 8). Results of mixtures organic and mineral components varied of 0.056±0.001 W/mK. That is more than mixture of two organic materials (approximately 17 %) and more than „Ekowool” (approximately 41 %). Highest λ was shown by samples of mixture of foamed glass with two different fractions (4–8 mm and 1–4 mm) by value of 0.071±0.001 W/mK, which is 81 % more than traditional loose material („Ekowool”). It could be explained by higher material density and air gaps, which arises from packing of loose components.

C. Force – Deformation

During the compression – deformation test, the applied pressure in N and related proportional deformation in mm of the test specimen was recorded at specific intervals for the purpose of plotting the stress-strain diagram (see Fig. 9). Compressive force F (in N) corresponding to 10 % and 30 % from maximum compressive strain were recorded by universal testing machine.

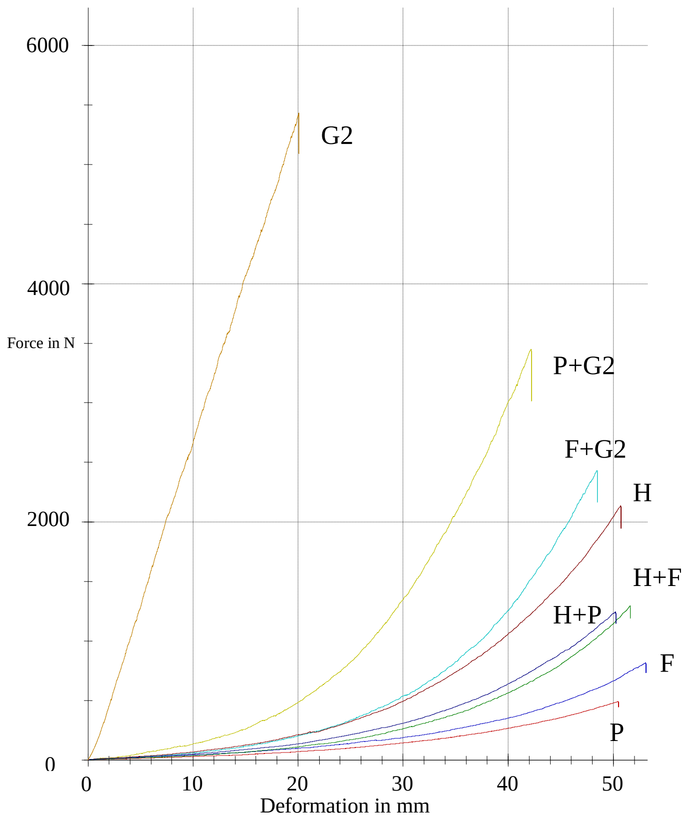

Fig.9. Compression – deformation curves; *G2 – foamed glass fr.4-8mm; F – flaxen shives; H – hemp shives; P – peels of wheat;*

The stiffness of loose insulation can be evaluated by modulus of elasticity, calculated from data of experimental curves (see Equation 4) and compressive strength of the deformation (see Equation 5).

$$E = \frac{\sigma}{\varepsilon}(MPa)\,,\ \ where\ \varepsilon = \frac{\Delta l}{l_0} \qquad (4)$$

$$\sigma = \frac{F}{A}(kPa)\,,\ \ where\ A = \pi \cdot r^2\ and\ F - the\ applied\ force \qquad (5)$$

The test specimens made of mineral raw materials reached significantly lower values of compressive strain (see Fig. 10).

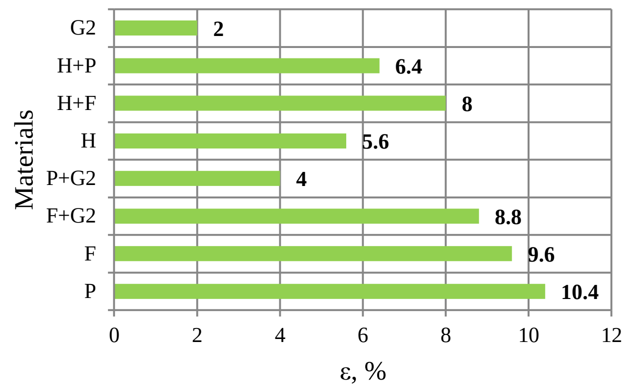

Fig. 10. Relative deformations of 10% loading; *F – flaxen shives, H – hemp shives, P – peels of wheat, G2 – foamed glass fr. 4–8 mm*

The minimum deformation values of 10 % loading represented composite of foamed glass (fr. 4–8 mm) and peels of wheat by value of 4 %. It can be explained by packing and dense particles of raw materials. As the loose density of both these materials was above the mean, then foamed glass must have been added in mixture more than peels of wheat. This aspect provided increase of mechanical stability.

Unfavourable results showed sample of mixture of foamed glass (fr. 4–8 mm) and flaxen shives by value of 8.8 %.

The test specimen deformations corresponding of 30 % from maximal compressive strain showed in Fig. 11.

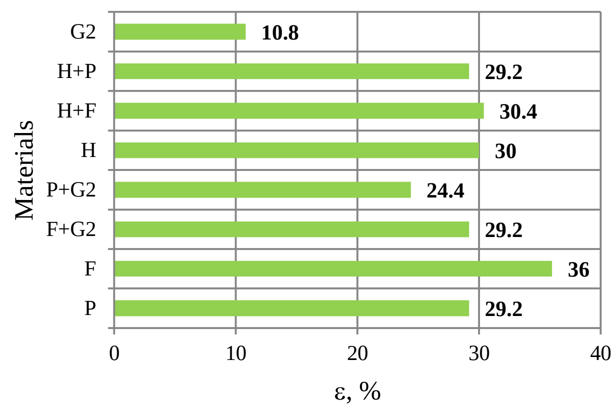

Fig. 11. Relative deformations of 30 % loading; *F – flaxen shives, H – hemp shives, P – peels of wheat, G2 – foamed glass fr.4–8 mm.*

The minimum deformation represented by composite of foamed glass (fr. 4–8 mm) and peels of wheat by value of

24.4 %, but the maximum showed composite between two organic raw materials.

D. Mechanical Stability

Mechanical stability of elaborated compositions is evaluated by the stress at 10% deformation. The best results of mechanical stability are achieved by the mixtures of organic and mineral loose insulation P+G2 and F+G2, as well as pure hemp shives material H. (see Fig. 12). The maximum stress at 10% deformation showed composite of foamed glass (fr. 4–8 mm) and peels of wheat by value of 22.2 kPa, but the minimum – 5.7 kPa – represented mixture of hemp shives and flaxen shives.

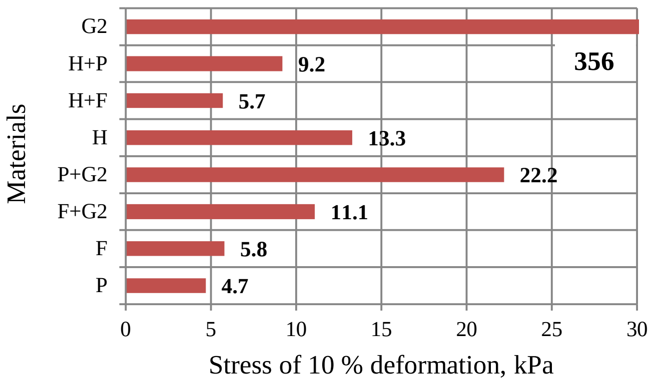

Fig. 12. Stress of 10 % deformation in kPa; *F – flaxen shives, H – hemp shives, P – peels of wheat, G2 – foamed glass fr.4–8 mm.*

Obtained results proved, that adding foamed glass in organic wool compositions increase stiffness of loose insulation and decreases deformations. Long-time self-comacting effect also may be reduced. It could be explained by improving grain size distribution and presence of hard particles in composite loose insulation.

E. Evaluation of Obtained Results

Selecting the most effective solutions of loose insulation is carried out by means of special rating diagrams (see Fig. 13). The diagram of given composition consists of three rating factors – heat transmission coefficient λ, stress in 10 % deformation and relative deformation ε of 10 % loading. Each factor is ranged by rating points, the highest rating (5 points) corresponds to the best desirable result. Maximal rating points are assigned to lower heat transmission coefficient λ, lower deformation ε and the highest value of stress in 10 % deformation. Taking into account this approach, the best solutions corresponds to maximal sum of the rating points. A greater value (11 points) of total sum (15 points) represents combination hemp shives and peels of wheat.

According to data of Fig. 13, the next perspective combinations of loose heat insulation materials are mixture of foamed glass (fraction 4–8 mm) and peels of wheat and mixture of hemp and flaxen shives. These multiple aggregate combination showed satisfactory results of heat transmission coefficient and the best values of mechanical stability. It must be noted, that compositions with foamed glass aggregate and organic wool components are more desirable, taking into account long-term stability sound insulation and increased fire resistance.

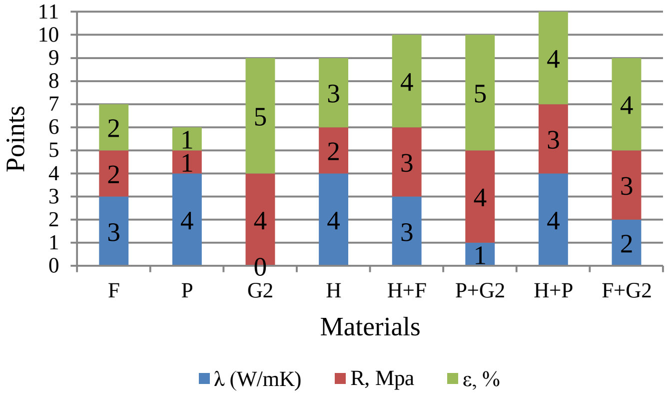

Fig. 13. Raiting points of factor, *F – flaxen shives, H – hemp shives, P – peels of wheat, G2 – foamed glass fr.4–8 mm, ε – deformation of 10 % loading, R – compressive strength, ρ – loose density*

F. Practical Use

The following example describes practical application of elaborated loose wool composite for insulation external 510 mm brick walls. Wooden framework is to be installed previously in order to provide 150 mm of flaxen shives and peels of wheat heat insulation. Thermal resistance of insulated wall with non-homogeneous layers is calculated in accordance with equation 6.

$$R_T = R_{SI} + R_1 + R_2 + R_3 + R_4 + R_5 + R_{SE}\left(\frac{\mathrm{m^2 \cdot K}}{\mathrm{W}}\right) \tag{6}$$

where

R_{SI} – thermal resistance of internal surface;

R_1 – interior decoration, plasterboard, $d = 0.013$ m, $\lambda = 0.25$ W/mK;

R_2 – horizontal framework construction with insulation material, $d = 0.05$ m;

R_3 – vertical framework construction with insulation material, $d = 0.15$ m;

R_4 – wind insulation, $d = 0.03$ m, $\lambda = 0.15$;

R_5 – ventilated air layer;

R_{SE} – thermal resistance of external surface.

$$R_T = 0.13 + \frac{0.013}{0.25} + \left(\frac{0.05}{0.07} + \frac{0.05}{0.047}\right) + \left(\frac{0.15}{0.07} + \frac{0.15}{0.047}1\right) + \frac{0.03}{0.15} + 0.04 = $$
$$= 7.532\left(\frac{\mathrm{m^2 \cdot K}}{\mathrm{W}}\right);$$
$$U_T = \frac{1}{R_T} = \frac{1}{7.532} = 0.132\frac{\mathrm{W}}{\mathrm{m^2K}}$$
$$U_{RN} = 0.18k = 0{,}18\frac{19}{20 - t_v};$$

t_v – the mean of outdoor air temperature during the heating

$$season\ (in\ Latvia - 1.9\ °C);\ U_{RN} = 0.18\frac{19}{20-(-1.9)} = 0.156\frac{\mathrm{W}}{\mathrm{m^2K}}$$

The given calculation shows that composite of flaxen shives and peels of wheat provide required value for wall thermal transmittance coefficient U at the Baltic states.

V. Conclusion

Loose thermal insulation from agricultural by-products is economically beneficial solution for filling frame wall systems. Experimental studies proved that use the mix of two component insulation makes possible to achieve good thermal insulation and improve mechanical stability of filling material.

The mix of flaxen shives and peels of wheat showed the best heat transmission coefficient 0.047 W/mK. Practical example proved, that 150 mm of this insulation is necessary for additional insulating of 510 mm brick wall in accordance with requirements of modern norm.

Combination of organic (flaxen shives or peels of wheat) and foamed glass (fraction 4/8 mm) is good alternative, which combines positive properties of mineral and organic component. Experimental results proved acceptable heat transmission coefficient (0.056 W/mK) and mechanical stability, too. Samples of mixtures are ecologically clean; there are no chemicals in those materials. It is proved that adding foamed glass aggregate decreases deformation deformability improves mechanical stability of loose insulation.

It must be emphasised possible improved fire resistance and long-term stability of composite insulation, comparing to pure organic wool insulation. In the future investigations fire resistance and biological stability of new composite insulation are to be estimated in detail. Important task is to achieve insulating properties to be competitive to other traditional heat insulation materials. This task may be achieved by controlling particle size distribution and getting more disperse particles of natural wool materials.

References

[1] A. Krēsliņš, "Ēku energoefektivitātes problēmas Latvijā," *Latvijas būvniecība*. no. 2, 2012, 4.–5. lpp. ISSN 1691-4058.

[2] LIAA, *Construction and building materials industry in Latvia* [online]. Riga: LIAA, 2014 [viewed 25 May 2015]. Available from: http://www.liaa.gov.lv/construction-and-building-materials-industry-latvia

[3] J. Zach, J. Hroudová, J. Brožovský, Z. Krejza, A. Gailius. „Development of thermal insulating materials on natural base fot thermal insulation systems, Science Direct," in *11th Int. Conf. on Modern Building Materials, Structures and Techniques*, MBMST 2013, 2013, pp. 1288–1294. e-ISSN 1877-7058. http://dx.doi.org/10.1016/j.proeng.2013.04.162

[4] D. Bajare, G. Bumanis, A. Korjakins. 2014. "New Porous Material Made from Industrial and Municipal Waste for Building Application," *Materials Science = Medžiagotyra*, 2014, vol. 20, no. 3, pp. 333–338.

[5] O. Belindževa-Korkla. 2002. *Norobežojošo konstrukciju siltumtehniskie aprēķini*. Rīga: RTU, 166 lpp., ISBN 9984326306

[6] H. Binici, M. Eken, M. Dolaz, O. Aksogan, M. Kara. „An environmentally friendly thermal insulation material from sunflower stalk, textile waste and stubble fibres," ELSEVIER, *Construction and Building materials*, 2014, pp. 24–33. e-ISSN 0950-0618. http://dx.doi.org/10.1016/j.conbuildmat.2013.10.038

[7] A. Korjenic. V. Petránek, J. Zach, J. Hroudová, "Development and performance evaluation of natural thermal – insulation materials composed of renewable resources," ELSEVIER, *Energy and buildings*, 2011, pp. 2518–2523. e-ISSN 0378-7788. http://dx.doi.org/10.1016/j.enbuild.2011.06.012

[8] H. R. Kymäläinen, A. M. Sjöberg. Flax and hemp fibres as raw materials fot thermal insulations, Science Direct, *Building and Environmental*, 2008, pp. 1261–1269. e-ISSN 0360-1323. http://dx.doi.org/10.1016/j.buildenv.2007.03.006

[9] THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION, *Directive 2012/27/eu* [online]. Official Journal of the European Union, 2012, p. 2. [viewed 20 May 2015]. Available from:http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:315:0001:0056:en:PDF

[10] A. Kamenders. Ēku energoefektivitātes prasības. Kas mainīsies un kam jāmainās. *Latvijas Architektūra*, no. 1, 2008, pp. 80–82.

[11] J. Zach, J. Brozovsky, J. Hroudova. "Research and development of thermal-insulating materials based on natural fibres," in *Proc. of the 10th Int. conf. Modern Building Materials, Constructions and Technics*. Lithuania, 2010. pp. 330–334.

[12] M. Strozs, G. Sahmenko, "Use of Straw–Clay Material in Walls," in *Civil Engineering '11: 3rd Int. Scientific Conf.: Proc.*, Latvia, Jelgava, 12–13 May. Jelgava: Latvia University of Agriculture, 2011, pp. 84–90.

[13] I. Appena. "Kaņepes jeb kanaizols siltinājumam," *Latvijas būvniecība*, 2012, no. 3, 64.–65.lpp.

[14] G. Zommere, A.Viļumsone, D. Kalniņa, R.Soliženko, V.Stramkalne, "Linu un kaņepju šķiedru uzbūves un celulozes satura salīdzinoša analīze," *Materiālzinātne*. Tekstila un apģērbu tehnoloģija. no. 8, 2013, 96.–104.lpp. ISSN 1691-3132. e-ISSN 2255-8888. http://dx.doi.org/10.7250/mstct.2013.016

[15] J. Zach, J.Brozovsky, J. Hroudova. "Investigation of anti-noise absorptions walls development with utilization of waste from agriculture," in *IABSE SYMPOSIUM BANGKOK 2009*. Switzerland, IABSE-AIPC-IVBH. 2009. pp. 502–503. ISBN 978-3-85748-121-5. http://dx.doi.org/10.2749/222137809796088684

[16] V. A. Lapsa. "Ēku siltumizolācijas problēmas un to risinājumi," *Latvijas būvniecība*, 2009, no. 5, 50.–54. lpp. ISSN 1691-4058

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